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NATURAL HISTORY OF PLUMMERS ISLAND, MARYLAND[1]

XVIII. The Hibiscus Wasp, an Abundant Rarity, and Its Associates (Hymenoptera: Sphecidae)

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The hibiscus wasp, *Ectemnius* (*Hypocrabro*) *paucimaculatus* (Packard), is a rather small (♀, 6–8 mm long) crabronine wasp with reduced yellow markings. Its closest relatives are *E. stirpicola* (Packard) and *E. spiniferus* (Fox). Until 1961 it was known from only a few specimens. There were 14 in the U. S. National Museum from scattered localities ranging from New Jersey to Florida, Texas and Missouri. The wasp was described from Illinois, and Fox (1898) in his revision recorded it also from New Jersey, the District of Columbia, and Florida. Three of the specimens in the National Museum were reared from a hibiscus stem at Black Pond, Fairfax Co., Va., in 1919, by F. C. Craighead, but no reference was made in the original brief rearing notes as to whether the hibiscus stem was dead or alive.

In 1961, while collecting at Plummers Island for an annotated list of the wasps of that locality (Krombein, 1963), I collected a male of *E. paucimaculatus* on 6 August along the Potomac River near the upper end of the island. In an attempt to secure some data on its life history, I tried to provide ready access to the soft pith in the hibiscus stems by topping a number of green and of dead hibiscus stems on mud flats along the river. Several years earlier a similar program of topping stag-

[1] The preceding number in this series was published in Proc. Biol. Soc. Wash., 76: 255–280, 1963. Publication costs of the present number have been defrayed by the Washington Biologists' Field Club to promote its primary objective of research on the fauna and flora of Plummers Island and adjacent areas.

horn and smooth sumac branches had resulted in data on several wasps nesting in the pith so exposed (Krombein, 1960). I examined the cut tips of these green and dead hibiscus stems at weekly or lesser intervals during the remainder of August and September 1961, but did not find any wasps nesting in them. However, while working in the hibiscus stands on 23 September 1961, I noticed two green stems each with a small (3–4 mm diameter) hole chewed in the side of the stem about half a meter from the ground. Upon splitting these open, I found that each contained the nest of another crabronine wasp (92361 A, B), *Euplilis* (*Corynopus*) *rufigaster* (Packard). (I discovered later that this species nests in cavities excavated by the hibiscus wasp, and does not itself make borings in green stems.) On 7 October 1961, I found another entrance hole in the side of a green hibiscus stem; this stem did contain a nest (10761 E) of the hibiscus wasp, from which adults emerged the following spring. Four additional nests of *E. paucimaculatus* were found in green hibiscus stems on 10 October 1961. I found 65 additional nests of this supposedly rare wasp in 1962, and 23 more in June and July 1963. I have combined the data on nesting architecture and life history from these nests with a few behavioral observations made in 1962 and 1963 in the following account of the biology of this wasp.[2]

I am indebted to the following of my colleagues in the Entomology Research Division for their esteemed services in identification of the prey and parasites of the wasps discussed herein: E. W. Baker, Acarina; B. D. Burks and C. F. W. Muesebeck, Hymenoptera; L. M. Russell, Homoptera; and R. H. Foote, C. W. Sabrosky, G. C. Steyskal and W. W. Wirth, Diptera. I am also indebted to J. de Beaumont, Musée Zoologique, Lausanne, Switzerland, for identifying *Pemphredon lethifer* form *littoralis* Wagn., to H. C. Huckett, Riverhead, N. Y., for identifying the first specimens of the fly *Eustalomyia vittipes* (Zett.), and to H. K. Townes, Ann Arbor, Michigan, for determining a pupa of the ichneumonid *Messatoporus*.

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[2] The nests or specimens on which this account is based are numbered as follows: 10761 E; 101061 A–D; 71162 A–J; 72162 C; 72262 A–C; 72862 A–E; 8362 A–D; 9162 A–M, P–R; 9962 A, B; 91662 A, C–I, L–N, Q–T, W–Z, AA–EE, GG–II; 51963 A; 52663 A–D; 6263 A–C; 61663 E–X; 72163 A. The specimens and notes are on deposit in the U. S. National Museum.

THE NESTING MEDIUM, *Hibiscus militaris* Cavanilles

Although a number of our North American crabronine wasps are known to nest in the soft pith of living plants, *Ectemnius paucimaculatus* is the first one to be recorded as chewing directly through the side of a green stem to reach the soft pith. The other species, e.g., *E. stirpicola* (Packard) and *E. spiniferus* (Fox), apparently nest only in soft pith which has been exposed by injury or pruning, such as stems of rose, elderberry and sumac. The hibiscus plants are not injured by penetration of the plant stem by the hibiscus wasp.

Three crabronine wasps outside of the United States have been recorded as chewing through green stems of growing plants to reach a nesting site in the pith. Berland (1932) reported *Dasyproctus bipunctatus jucundus* (Arnold) as nesting in gladiolus stems in Johannesburg, South Africa, and causing great damage. J. van der Vecht (1951) found *Dasyproctus ceylonicus* (Sauss.) nesting in green stems of sorghum in Java; this species also entered green stems of *Helianthus* and *Clerodendron*. Tsuneki (1960) summarized accounts by several other Japanese hymenopterists, who reported that *Ectemnius* (*Hypocrabro*) *rubicola nipponis* Tsuneki entered and nested in the green stems of such herbs as *Sophora, Macleya, Gladiolus, Erigeron, Aster* and *Artemisia*. (Oddly enough, the nominate race of *rubicola* (Duf. and Per.) from Europe nests in the soft pith of broken or pruned stems of *Rubus* and *Sambucus*.)

The plant which *E. paucimaculatus* uses (exclusively ?) as a nesting site is the halberd-leaved hibiscus, *Hibiscus militaris* Cav.[3] It has a wide range in eastern North America, where it occurs along river and stream edges from Pennsylvania west to Minnesota and south to Florida and Texas. On Plummers Island and along the adjacent banks of the Potomac River it grows on mud flats (Figs. 1, 2) which are subject to prolonged inundation by high water during the spring floods and to occasional short periods of immersion during heavy summer storms.

This hibiscus is a perennial which sprouts each spring from rootstocks. The old, dead, dry stems remain attached to the rootstocks for one or more years. The new growth begins to leaf out early in May. On 19 May, the date on which the first male and female wasps were observed in 1963, the young hibiscus plants were mostly 15–30 cm high. The stems were quite succulent. I split the stem of a 45-cm plant and found that it had a central cavity 1–2 mm wide extending from the base to a height of 30 cm. The pith was too juicy on this date to be used in nest construction. A week later one of the stems was 60 cm tall and had a central cavity with a diameter of 2.5 mm about 9 cm above ground level. On 2 June

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[3] There is a possibility that the hibiscus wasp may attempt occasionally to nest in other herbaceous plants growing along the river margin. In 1963 I found a specimen of *Polygonum lapathifolium* L. with a stem about 10 mm in diameter in which an insect had made a boring through the side. The entrance hole was exactly like that made by the hibiscus wasp in an hibiscus stem. However, the pith of this plant was so juicy that the insect apparently did not attempt to nest in the central cavity.

1

2

some plants were a meter high, by 16 June the average height was a little over a meter, on 28 June the average height was a meter and a half, and by 6 July some plants were 2 meters high. At maturity the plants are 2 to 2.5 meters high. The plants begin to bloom late in July.

In most plants there is a central cavity of varying diameter and length, and it is in this cavity that the wasp nests. The cavity begins at or slightly above ground level and usually extends upward for half to two-thirds the height of the plant, gradually narrowing until it becomes evanescent. The diameter of the central cavity at the base of a mature plant is usually 5–6 mm, though it may be as large as 7 mm. In plants of the same size the diameter of this cavity at a given distance from the ground may vary as much as 5 mm. The cavity is caused by the differential in growth rates of various parts of the stem. The cells forming the inner pith layer multiply much more slowly than the others. Consequently, as the stem increases in girth and height, the pith is pulled apart to form a central cavity.

THE NEST ARCHITECTURE OF THE HIBISCUS WASP

In beginning the entrance boring, the wasp rasps away a roughly elliptical area of green epidermis about 5 mm high by 3 mm wide. She then chews away bits of fiber to form a cylindrical boring about 3 mm wide perpendicular to the axis of the plant (Figs. 3, 4). I made some detailed observations on one female (72862 C) as she constructed her entrance boring on 28 July 1962. She had selected a spot 40 cm above the ground where the stem had a diameter of 17 mm. I first observed her at 1355 hours; at that time she had penetrated only 1 or 2 mm into the stem, and I estimated that she had started the boring at 1330. She braced herself on the stem with all legs, head upward, and chewed out narrow strips of fiber 2–3 mm long, letting them drop at random on the ground beneath. At 1418 she flew off for a few seconds, returned and then left again because a phorid fly was investigating the entrance. The wasp finally returned at 1436 and continued the excavation. By 1450 the entrance was deep enough so that the wasp could get her entire head inside. By 1510 her head and thorax were both in the excavation. By this time the wasp was working on all sides of the boring so that it was circular in cross-section. She flew off at 1553; at this time the boring was 6 mm deep and had not penetrated to the central cavity. She had not returned to the excavation by 1618, but she was at work there by 1625. As she increased the length of the boring, the wasp backed partly out and passed the gnawed-out bits of fiber backward with her hind legs and tip of her abdomen; sometimes she crawled out backward, pushing the bits of fiber behind her. This was happening every 30–40 seconds

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PLATE I. *Hibiscus militaris* Cav., the halberd-leaved hibiscus. Fig. 1, Several clumps of hibiscus on mud flat along river bank, October 1962. Fig. 2, Habitat view along Potomac River, large hibiscus stand in right foreground, August 1963. (All photographs, Plates I–VI, by author.)

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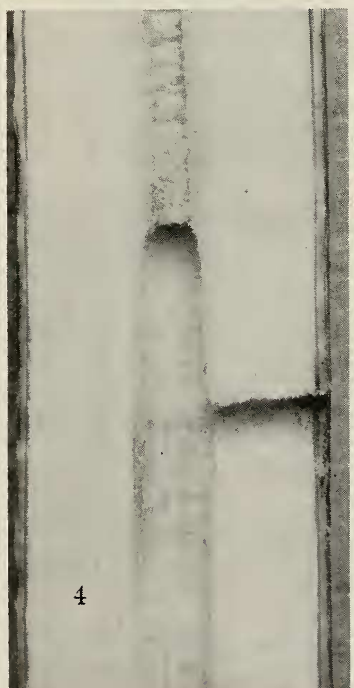

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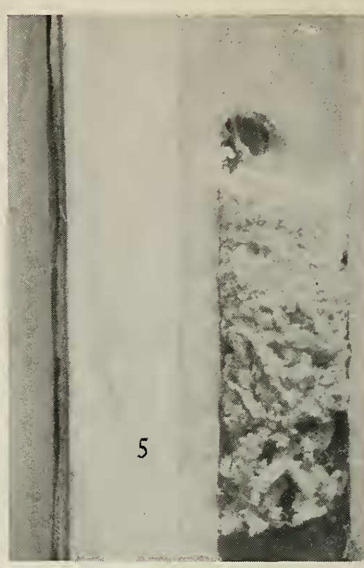

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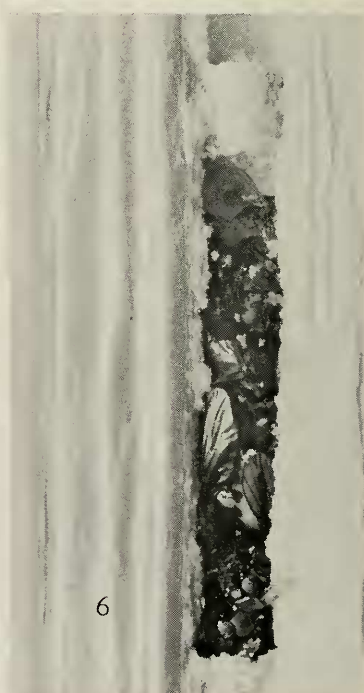

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by 1630, and the gnawed-out material was now composed of quite fine particles. Apparently the wasp reached the central cavity at 1659 when she pushed out the last load of pith. She went out of sight and reappeared at 1701 at the entrance head first, a sure sign that she had reached the central cavity.

In a second nest (72163 A) I observed a female just beginning to gnaw into a green stem at 1420 on 21 July 1963. I did not keep this wasp under observation, but by 1720 on the same day she had chewed through to the central cavity.

In nests begun in June the entrances were gnawed out 10 to 60 cm (mean 31 cm) above the ground where the stem diameter ranged from 8 to 15 mm (mean 11 mm). In July to September, after the plants reached maturity, the nest entrances were 10 to 70 cm (mean 39 cm) above the ground, and the stem diameter at the entrance was 10 to 22 mm (mean 16 mm). The diameter of the entrance itself was 2.5 to 4 mm (mean 3.3).

After reaching the central cavity the female went downward a considerable distance and constructed a plug from particles of pith. The only exceptions to this procedure were when the central cavity had a diameter of more than 4 mm or when the cavity closed in solidly beneath. This plug was built at distances of 5.5 to 33 cm (mean 18 cm) below the entrance in June nests, and at distances of 7 to 43 cm (mean 26 cm) in later nests. The plugs were 1 to 60 mm in thickness (mean 9 mm), and were constructed from bits of pith which the wasp rasped from the upper end of the central cavity. Occasionally, a wasp made a series of several such plugs before provisioning any cells. In two nests where the central cavity closed in solidly below, the wasp did not make a plug of pith particles. In a number of nests where the diameter of the central cavity exceeded 4 mm below the entrance, the wasp built no cells below the entrance but went upward and built cells in that part where the diameter was less than 4 mm.

The wasp then built a series of linear cells separated by partitions of pith particles (Fig. 7*b*). Forty-one cells from which females were reared ranged from 8 to 21 mm in length (mean 14 mm); 60 male cells were 5 to 23 mm long (mean 12 mm). Although males were produced in cells having a shorter mean length than female cells, it was impossible to predict the sex of the wasp from the length of the cell because of the overlapping ranges in the two sexes. The partitions of pith particles capping the cells were 1 to 15 mm thick (mean 4 mm). The lower end

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PLATE II. *Ectemnius paucimaculatus* (Pack.), the hibiscus wasp; details of nest construction. Fig. 3, Entrance to incompleted nest 72862 C, 3 August 1962, × 2.5. Fig. 4, Entrance boring in profile, incompleted nest 72862 C, 3 August 1962, × 2.5; note short plug of pith particles above entrance and evanescent central cavity above plug. Fig. 5, Closing plug below entrance, completed nest 71162 E, 11 July 1962, × 3.6; note longer, looser pith particles below, and smaller, firmly packed particles above. Fig. 6, Cell 4, nest 9162 C, 2 September 1962, × 3.9; large flies are *Melanagromyza diantherae* (Mall.), smaller flies are *Hydrellia* spp.


7a
7b

of the partitions below the entrance was roughly convex and the upper end smoothly concave due to pressure from the wasp's head during construction (Fig. 7*b*). The boring diameter in which the cells were constructed ranged from 2.5 to 4 mm.

Ordinarily there were no empty intercalary cells between the stored series in the lower part of the nest. However, 11 of the nests had such cells; there was one intercalary cell in each of 9 nests, and two and three intercalary cells respectively in the other 2 nests. These cells were 10 to 95 mm long. The reason for constructing these cells is unknown; in some cases it may have been occasioned by infestation by phorids in some of the preceding cells.

The number of stored cells below the entrance ranged from 1 to 13 in 58 completed nests, with a mean of 5 cells per nest. There was an empty vestibular cell 10 to 230 mm long between the uppermost stored cell and the entrance; in three nests there were two such vestibular cells separated by pith partitions. Above each vestibular cell was a closing plug of pith particles 3 to 50 mm thick (mean 21 mm) which usually extended upward right to the entrance. Usually the closing plugs consisted of rather loose, larger pith particles at the lower end which gradually became smaller and more solidly compacted above.

Occasionally the wasps nested above the entrance. This happened if the central cavity had a diameter greater than 4 mm below the entrance; it also occurred occasionally after a wasp had made a series of provisioned cells below the entrance. In either case the procedure was the same. The wasp made a plug of pith particles some distance above the entrance unless the central cavity became evanescent. Then she constructed a linear series of cells separated by partitions of pith fragments (Fig. 7*a*). In these partitions, as contrasted to those below the entrance, the upper end was roughly convex and the lower end smoothly concave due to pressure from the wasp's head during construction (Fig. 7*a*). The pith fragments to separate these cells were obtained from the sides of the central cavity. The number of stored cells above the entrance ranged from 1 to 8 in 21 completed nests, with a mean of 3 cells per nest. Each series of cells above the entrance had an empty vestibular cell between the last (lowest) stored cell and the closing plug, which was constructed just above the entrance. In those nests where there was a series of cells both below and above the entrance, some of the pith particles were probably borrowed from the plug closing the lower series so that the wasp could construct the closing plug for the upper series.

The largest number of provisioned cells in a single nest (91662 Y) was 18, a series of 12 below the entrance and one of 6 above the entrance. In this nest there was a pith plug 29 cm below the entrance, then a

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PLATE III. *Ectemnius paucimaculatus* (Pack.), the hibiscus wasp; completed nest 9962 A split open, 9 September 1962, × 1.0. Fig. 7*a*, Cells 6–13 and entrance boring (cell 6 at top). Fig. 7*b*, Cells 1–5 (cell 5 at top) and entrance boring. Note closing pith plugs both above and below entrance and solid pith above cell 6.

series of 12 provisioned cells in the next 20 cm, then a vestibular cell of 8.5 cm and a 5-mm closing plug below the entrance. Cells 13–18 were in a 10-cm space 21 cm above the entrance; below these provisioned cells was a vestibular cell of 9 cm and a closing plug of 20 mm just above the entrance.

There were 19 stems in which two wasps nested, using separate entrances. In a dozen stems the second wasp nested above an old *paucimaculatus* nest from which the occupants had already emerged, but in seven stems nesting by the two occupants may have gone on concurrently. In these multiple nests the later female chewed out her entrance some distance above the earlier occupant, went downwards in the central cavity, and constructed a pith plug above the uppermost cells of the first wasp or above the entrance to the first nest. The rest of her nest construction proceeded in the orthodox manner as detailed above. There was still another stem which had been penetrated three separate times by wasps in the first half of June, but only the lowest occupant had begun provisioning cells when the stem was gathered on 16 June.

I encountered three other anomalous nests in this study. In each of three stems the wasp excavated a sinuous boring in the pith, separated from the central cavity. In one nest there were three cells in a section of boring 7 cm below the entrance with two more cells in a section 4 cm long above the entrance; the central cavity was empty and may have been too wide to permit nesting. In the second nest the central cavity had been used by another hibiscus wasp earlier; the second one made her entrance 9 cm below that of the first. A sinuous boring went downward in the solid part of the stem for 9 cm; there were three cells at the end of this boring, a vestibular cell of 20 mm and a closing plug of 10 mm at the entrance; above the entrance was an empty sinuous boring 40 mm long which supplied the pith particles for the partitions and plugs in the nest proper. In the third stem there was an old abandoned nest in the lowest 30 cm of the central cavity. There was a second entrance 40 cm above that of the older nest. The second wasp made a spiral boring in the stem tissue which made a complete turn around the stem to a depth of 82 mm. There were two cells in the lower 30 mm, then a vestibular cell and a closing plug of 11 mm at the entrance.

I found three stems in each of which the wasp made an entrance, and then constructed a series of several pith plugs at varying distances from the entrance but did not store any prey. Each of these abortive nests was made by a different individual. I am unable to suggest any reason for this anomalous behavior, unless possibly these were nests in which the wasps were just about to bring in the first fly. (See the later discussion on incompletely stored cells under the heading, Prey of the Hibiscus Wasp.)

LIFE HISTORY OF THE HIBISCUS WASP

The wasps overwinter as resting larvae, transform to pupae early in May, and the adults emerge during the latter half of May. The hibiscus plants are too small and succulent at the time the wasps emerge to permit nesting. In 1963 the female wasps began to penetrate the side of the stem on 26 May, a week or more after their emergence. However, as late as 2 June the pith had not dried out sufficiently to enable the wasps to form the pith partitions which are an integral component of the nest. The wasps began to provision the cells with flies between 2 and 9 June 1963, probably about 7 June judging from one nest which contained 1^{+} cells and 19 flies on 9 June.

The wasp lays her egg on the first fly placed in the cell. It is deposited transversely on the venter on the left side between the head and the left foreleg (Fig. 8). It is opaque white, sausage-shaped, and about 1.8 × 0.5 mm.

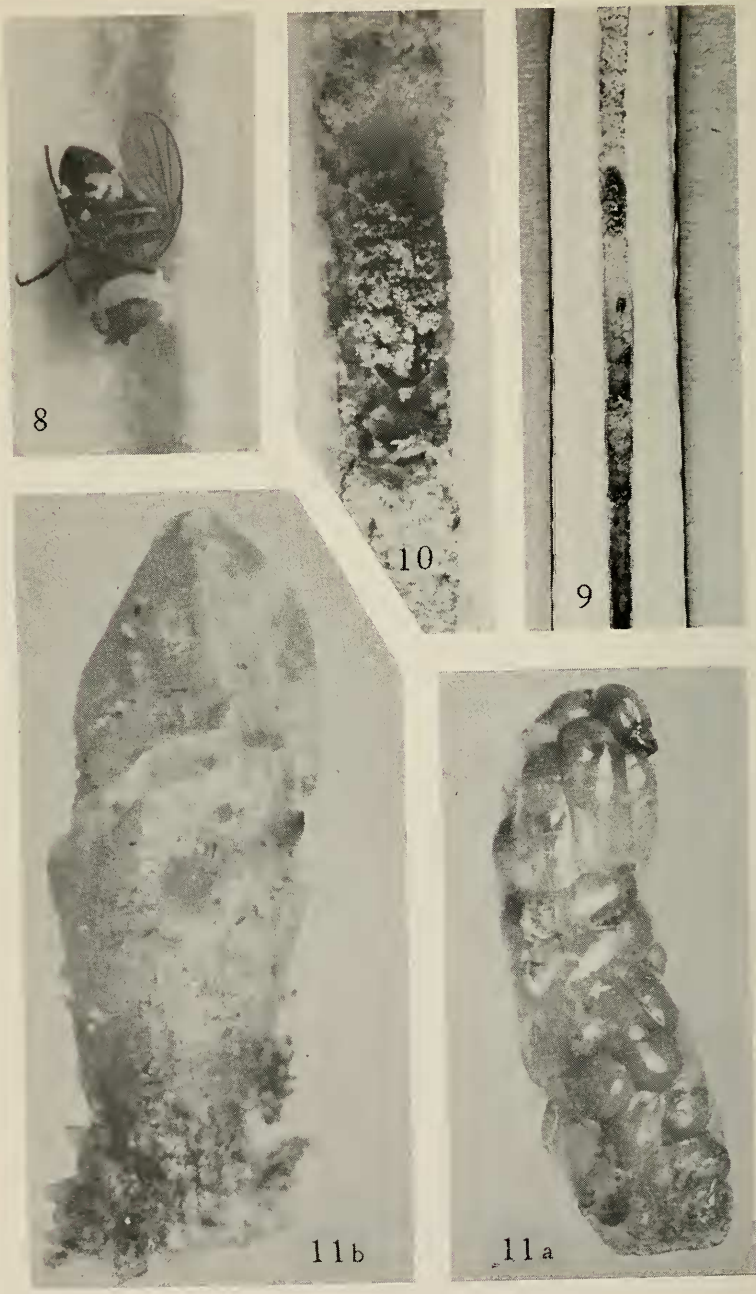
Very limited data are available on the duration of the various developmental stages, because these early stages are very subject to desiccation after the stem is split. The summer generation requires approximately 24–31 days from egg to adult. Apparently the egg hatches in 2^{+} days and the larva reaches maturity about 7–8 days after the egg is laid. The spinning of the cocoon and voiding of the meconium require 1^{+} days. The prepupal stage lasts 5–10 days, and 10 to 11 days elapse between pupation and emergence of the adult.

The cocoon is light tan, fusiform, has a small pore at the anterior end, and differs in no essential detail from that of most other species of the subgenus *Hypocrabro* (Figs. 7, 11*b*). The prey remains are compacted around the lower end of the cocoon. Female cocoons are 10–11 mm long (mean 10.3) and male cocoons are 6–10 mm (mean 9.1).

The cocoons are always oriented with the anterior end upward, regardless of whether the cells are below or above the entrance. This is a definite indication that the larva of the hibiscus wasp orients its cocoon according to the influence of gravity. Cooper (1957) found that larvae of vespid wasps in horizontal borings oriented their cocoons in relation to the cell partitions with the anterior end toward the convex, rough, inner surface of the plug closing the cell, and the posterior end toward the smooth, concave surface of the plug closing the preceding cell. This cannot be true in the hibiscus wasp because, although the cell partitions below the entrance have the rough, convex surface downward and the smooth concave surface upward (Fig. 7*b*) the reverse is true with cell partitions above the entrance (Fig. 7*a*).

This raises the problem as to how the wasps in the cells above the entrance get out of the nest. They could do this by turning around in the cell and leaving through the entrance, provided the boring diameter was large enough; or, they could chew their way out through the side of the stem. The latter method is more likely. I found an old nest from which the occupants had escaped by chewing a diagonal boring through the stem 13 cm below the original entrance.

Females from the overwintering population nest throughout June, and possibly to some extent during July. Progeny from their earliest nests emerge early in July, and can construct nests from which additional


8
10
9
11b
11a

adults will emerge in August. However, progeny from later nests constructed by females of the overwintering population emerge so late that progeny from their nests overwinter as prepupae and emerge as adults the following spring. Consequently, there are two complete generations and a partial third, annually. In 1962 occupants of nests stored early in July emerged that same summer, but occupants of nests provisioned about 20 July or later did not emerge until the following spring. Nesting is more or less continual from early June until early September.

Some nests produced only males, some only females, and some produced both sexes. In nests which produced only males the occupants of individual nests emerged over periods ranging from 1–10 days; the median emergence period for males from a single nests was 3 days. Three nests produced females only, and these emerged respectively over periods of 1, 7 and 10 days. In nests producing both sexes the emergence from a single nest ranged from periods of 6–19 days, with a median emergence period for a single nest of 16 days. Males emerged several days before females; in the mixed nests there was a period of 0–12 days (average 6) between emergence of the latest male and earliest female.

SEX RATIO AND SEQUENCE IN NESTS OF THE HIBISCUS WASP

There was considerable mortality in the nests because of mold, parasites, and injuries sustained when I opened the stem. I reared 5 females and 12 males from 88 cells provisioned during June and early July, and 55 females and 97 males from 306 cells provisioned later in the summer.

After I recorded details of the nest architecture, I placed the cocoons in separate, numbered glass vials for rearing. Therefore, I can give some definite data on arrangement of the sexes in 17 mixed nests. Females were produced in the lower cells and males in the upper cells in seven nests, and the converse was true in three nests. There were 2 to 7 cells in 8 of these nests, and 8 and 13 in the others. Inasmuch as there was some mortality in all but two nests, it is possible that some nests might have shown a random arrangement of sexes had there been more survivors. In the other seven nests, the arrangement was as shown in the following table (an *x* indicates mortality due to parasites or injury). The nest entrance was above the uppermost cell in nests 9162 P, 91662 F, T and CC. In nests 9162 K, 91662 Y and AA the nest entrance was above cells 8, 12 and 7 respectively. The only conclusion which can

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PLATE IV. Prey and parasites of *Ectemnius paucimaculatus* (Pack.), the hibiscus wasp. Fig. 8, *Melanagromyza dianthcrae* (Mall.) fly with wasp egg attached between head and forelegs, cell 6, nest 71162 C, 11 July 1962, × 6.1. Fig. 9, Puparium of anthomyid fly, *Eustalomyia vittipes* (Zett.), in nest 91662 Z, 20 September 1962, × 0.9; note that maggot destroyed contents of cells 1–3 (below puparium) and then wriggled upward into pith-closing plug to pupate. Fig. 10, The same puparium, × 2.9. Fig. 11*a*, Resting larva (head upward) of hibiscus wasp, cell 1, 9162 D, containing 28 capsule-like, pupal cells of *Tetrabaeus americanus* (Br.), November 1962, × 11.2. Fig. 11*b*, Cocoon from which the resting larva was extracted, × 11.2.

fairly be drawn from these data is that the sequence of sexes in the cells is a purely random one.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
9162 K	♀	♂	♂	♀	♀	♀	♀	♂	*x*	*x*								
9162 P	*x*	*x*	♀	♀	♀	♂	♀											
91662 F	♀	♂	♂	♀	♂	♂	♂	♂	♂									
91662 T	♀	♀	♂	♀	♂	*x*	♂	♂	♂	♂	♂	♂	♂					
91662 Y	♀	♀	*x*	*x*	♂	♀	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*	*x*
91662 AA	♀	♀	♀	*x*	♀	*x*	♀	♀	♂	♀								
91662 CC	♀	*x*	♂	♀	*x*	*x*												

PREY OF THE HIBISCUS WASP

I was never so fortunate as to see the wasp catch a fly. I have watched females engaged in what I supposed was hunting behavior. They flew from leaf to leaf, alighting for a few seconds, and then flew on to another leaf. Most of this hunting was done on leaves of the hibiscus, a meter or less above the ground surface, but occasionally the wasps alighted on adjacent scrubby willows. Probably the wasp merely pounces on any fly which it may surprise resting on a leaf. On 28 July I captured a female wasp (72862 A) resting on a leaf of hibiscus at 1200 hours, clutching a muscid fly, *Lispe albitarsis* Stein. The fly was not deeply paralyzed and could wiggle its legs and wings. G. C. Steyskal has pointed out that the Ephydridae, which constitute approximately two-thirds of the prey, are found either on or just a few centimeters above mud flats. Most of the identified specimens of prey belong to several species of Ephydridae and Agromyzidae, which are common in this specialized habitat.

I preserved the prey from a number of completely and partially provisioned cells. Consolidated prey records from 17 nests were determined as follows:

Dolichopodidae
- *Dolichopus ovatus* Lw.—1
- *Dolichopus* n. sp.—1

Agromyzidae
- *Melanagromyza diantherae* (Mall.)—85
- Gen. & sp.—1

Ephydridae
- *Notiphila carinata* Lw.—80
- *Notiphila erythrocera* Lw.—1
- *Notiphila* sp.—7
- *Hydrellia* spp.—109
- *Scatella picea* (Wlkr.)—1

Otitidae
- *Eumetopiella rufipes* (Macq.)—4
- *Chaetopsis* sp.—1
- Gen. & sp.—1

Lauxaniidae
Camptoprosopella angulata Shew.—1
Lonchaeidae
Lonchaea polita Say—1
Sciomyzidae
Sepedon armipes Lw.—4
Sepedon sp.—1
Dictya texensis Curr.—1
Sphaeroceridae
Leptocera richardsi Sabr.—1
Muscidae
Coenosia (*Limosia*) *atrata* Wlkr.—1
Lispe albitarsis Stein—6

The number of flies stored per cell was dependent on two factors, the size of the cell and the size of the prey captured. Of the species stored most commonly the agromyzid is a large, bulky fly, 3.5–5 mm long, and the ephydrids are smaller, 1.8–3.2 mm long. Five cells provisioned entirely with the *Melanagromyza* contained 7, 7, 12, 13, and 13 flies, respectively, and were 10 to 16 mm long; two cells provisioned completely with ephydrids held 15 and 26 flies and were 12 and 16 mm long, respectively. Several completely provisioned cells contained only seven flies, larger species like *Melanagromyza* and *Sepedon*. There were 31 flies in the completely provisioned cell containing the largest number of flies; the cell was 25 mm long and contained 22 *Hydrellia*, 8 *Notiphila* and 1 *Dolichopus*. Some wasps were apparently quite successful in exploiting the population of a single species for prey—for instance, one wasp used only *Melanagromyza* in four cells except for one ephydrid, and another used almost entirely several species of Ephydridae in three cells except for three *Melanagromyza*. Other wasps were much less selective: One put in a single cell 1 lonchaeid, 1 agromyzid, 4 specimens of two species of Otitidae, and 1 ephydrid; another used for one cell one dolichopodid, 2 agromyzids, 1 muscid, and 11 specimens belonging to two species of Ephydridae.

Species of *Melanagromyza*, *Hydrellia*, *Notiphila*, *Dolichopus*, and *Lispe* were preyed on throughout the nesting period of the wasp. Species of the other genera were stored during the latter part of the summer. However, I have prey records from only two nests in the first half of June, so it is quite possible that a larger sample would reveal that additional species are used early in the season.

I opened several stems in which the cells were still being provisioned. Analysis of these showed that probably the wasp usually accumulates the required number of flies for one cell in a space below the entrance before actually storing the cell and placing an egg on the first fly brought into the cell. There are usually one or more loose plugs and one solid plug of pith particles between these flies and the entrance. Presumably these plugs are to keep out parasites or predators, though they can hardly be very effective, judging from the parasitism rate. In one nest (72262 B) which had just been started, there were three paralyzed flies and no wasp egg in a space of 8.2 cm above the firm pith plug at the bottom of the boring, then a loose pith plug 50 mm long, another empty space of 6.5 cm, followed by a firmer pith plug of 5 mm and then empty for 16.6 cm to the entrance. Another nest, which contained five completed cells, showed exactly the same architecture above the incompletely stored sixth cell. Several other nests also had the same arrangement for the incompletely stored cells. In still another nest (9162 J) there was one completed cell, then an empty space 5 cm long containing 29 small flies but no egg, and then 20 mm of loose pith particles almost to the entrance, with some of the particles arranged to form barriers.

Very little information is available on the rate of provisioning. It is likely that the wasp requires ⅔ to 1⅓ days to provision a single cell. In one nest, eggs were present in the three outermost completed cells when the stem was split. In another nest, the larvae in three consecutive cells matured over a 4-day period; when this nest was opened there was a nearly mature larva in the first cell, successively smaller larvae in the next three cells, and an egg in the fifth cell. Earlier I described construction of the entrance boring by one wasp (72862 C). This entrance was completed late on 28 July. I picked up and split this stem early on 3 August, at which time there had been 3¼ sunny days available for provisioning cells. On this date there were two fully stored cells, each containing 26 flies, with 13 additional flies available for cell 3. There was a small larva in cell 1, and an egg ready to hatch in cell 2. In another nest (72163 A) the wasp made the entrance boring on 21 July. I picked up this nest on 27 July and opened it. It contained 8 provisioned cells and a vestibular cell. Probably it was completed on 26 July. Every day between 22 and 27 July was sunny.

When the female wasps returned to their nests, they sometimes flew directly to the entrance and crawled in rapidly. At other times they alighted just below the entrance and crawled in quickly. I timed only one provisioning flight. This particular wasp (8362 A) left her nest at 1103, and returned at 1129 with a fly clutched tightly beneath with her legs.

MISCELLANEOUS BEHAVIORAL NOTES ON THE HIBISCUS WASP

Although males were abundant throughout the nesting period, I never witnessed mating behavior. Apparently the males like to rest in abandoned borings in the cut ends of dead hibiscus stems. On 3 August 1962, at 1015, I found one male in such a boring in one dead stem, and two males in a similar boring in a second dead stem.

I have never observed the hibiscus wasp visiting flowers for nectar or honeydew secretions of other insects on leaves.

The hibiscus wasp was not superseded in its nests by other species of wasps, and so far as I was able to determine, there was never any competition between two females for the same entrance. However, the crabronine wasp, *Euplilis rufigaster* (Packard), appropriated the empty inner cavity above the entrance in seven stems in which the hibiscus wasp nested. A trypoxylonine wasp, *Trypoxylon* (*Trypoxylon*) sp., also constructed one cell in a similar situation in another nest. Presumably the wasps of these other two species did not nest concurrently with the hibiscus wasps, but appropriated these ready-made cavities after the hibiscus wasps had completed their closing plugs.

PARASITES AND SYMBIONTS OF THE HIBISCUS WASP

The hibiscus wasp is subject to attack or infestation by a number of other arthropods. The most common enemy was the scavenger phorid fly, *Megaselia aletiae* (Comstock). It destroyed the contents of 30 out of 93 cells in 18 nests. It also occurred in six other nests on which I made no detailed notes.

There was another group of dipterous parasites which exerted a heavy pressure on the wasp population, not because of the abundance of individuals but because each individual parasite destroyed several wasp cells in order to reach maturity. These were: the anthomyiid, *Eustalomyia vittipes* (Zetterstedt), of which six individuals destroyed 10 of 23 cells in four nests (Figs. 9, 10); the sarcophagid, *Macronychia aurata* (Coquillett), of which one individual destroyed 7 of 9 cells in one nest; the sarcophagid, *Ptychoneura aristalis* (Coquillett), of which one individual destroyed 2 of 10 cells in one nest; and three unidentified muscoid flies which destroyed 10 of 17 cells in three nests (at least one of these flies was different from any of these three muscoids mentioned earlier in this paragraph).

Several species of Hymenoptera are also important parasites of the hibiscus wasp. A perilampid, *Perilampus canadensis* Crawford, parasitized 6 of 34 cells in six nests. The torymid, *Diomorus zabriskiei* Cresson, parasitized 12 of 51 cells in six nests. The platygasterid, *Tetrabaeus americanus* (Brues), infested 17 of 56 cells in eight nests (Fig. 11).

The symbiotic saproglyphid mite, *Vidia cooremani* Baker, was found in 4 of 10 cells in two nests. Hypopi of this mite were also found on the abdomens of four males of the hibiscus wasp (51963 A, 52663 B, C, D) netted on 19 and 26 May 1963.

The toll exacted by these parasites is occasionally quite devastating. For example, in a 9-celled nest (72162 C), *Perilampus* was reared from the second cell, *Macronychia* destroyed the last seven cells; *Megaselia* also occurred as a scavenger on the prey remains left by *Macronychia*. In one 6-celled nest, *Megaselia* infested the second cell, *Diomorus* parasitized the third and fifth cells, *Tetrabaeus* parasitized the sixth cell, and the contents of the fourth cell were attacked by mold. Finally, not a single hibiscus wasp developed in one 12-celled nest: cells 1, 3, 4 and 5 were parasitized by *Diomorus*; the contents of cells 2 and 8 were attacked by mold; cells 6, 7, 10, 11 and 12 were parasitized by *Tetrabaeus* and cell 9 was infested by *Megaselia*.

ASSOCIATES OF THE HIBISCUS WASP

Crossocerus (*Blepharipus*) *stictochilos* Pate

This crabronine wasp built one nest (9162 S) in a green hibiscus stem nested in earlier by *Ectemnius paucimaculatus*. The nest of the latter wasp was in the central cavity entirely below the entrance. The *Crossocerus* used only the section of central cavity above the *paucimaculatus* entrance. Both wasps used the same entrance, but not concurrently, because the occupants of the hibiscus wasp nest had emerged prior to 1 September 1962 when I picked up the stem. *C. stictochilos* is about as large as the hibiscus wasp; females from this single nest were 6–7 mm long.

The *Crossocerus* female first constructed a plug of pith particles 8 mm thick about 10 cm above the nest entrance. Then she constructed cells 1 through 5, respectively 11, 8, 12, 7 and 7 mm long, which were sealed below by partitions of pith particles 4, 8, 4, 5 and 12 mm long. The central cavity was empty between the partition capping cell 5 and the entrance, there being no closing plug just above the entrance.

The cocoons contained resting larvae when the nest was opened on 1 September. Females emerged the following spring from the cocoons in cells 1, 3 and 5, a male from that in cell 4; a male wasp died in cell 2 during the pupal stage. There are at least two generations a year because I have taken adult wasps at Plummers Island from early in June until early in September.

The cocoon is light tan, fusiform in shape, and 7–8 mm long. It is superficially very similar in appearance to that of the hibiscus wasp, but is more delicate and lacks the small pore at the anterior end. Dipterous remains, which were too fragmentary for further identification, were massed around the posterior end of the cocoon.

Euplilis coarctata modesta (Rohwer)

This crabronine wasp was reared from six completed nests (101061 F; 8362 L; 9962 C, F, G, H) in dead hibiscus stems. It is a somewhat smaller species than the hibiscus wasp; reared females were 5 to 6.5 mm long. The female wasp always entered the pith at the cut or broken end of the stem rather than using the entrance excavated by a hibiscus wasp. In some cases she probably merely utilized the exposed central cavity, because in three nests there were plugs of pith particles 1 to 8 mm thick at distances of 14 to 42 cm from the cut or broken end of the stem. In the other three nests the wasp or some other insect chewed out a straight or sinuous boring which ended in solid pith 17 to 26 cm from the broken end of the stem. On 27 July 1963 I captured a female *E. coarctata modesta* (72763 A) just after she removed some fine pith particles from the broken tip of a dead hibiscus stem having a diameter of 12 mm. She had chewed out a sinuous boring 10.7 cm long and 1.5–2 mm wide. The pith in which she tunneled must have been almost solid, because the central cavity 10.7 cm below the broken end of the stem had a diameter of only 1 mm.

The wasps constructed a linear series of cells separated by pith partitions formed from small particles chewed from the sides of the boring. Five cells from which females were reared had a mean length of 11.2 mm (range 10–13), and 21 male cells had a mean length of 9.6 mm (range 7–13). The pith partitions closing the cells were formed from rather loose pith particles as compared with the firmly compacted plugs closing the cells of the hibiscus wasp. The partitions of this *Euplilis* had a mean length of 8.5 mm (range 2–28).

Apparently the wasp usually constructed an empty vestibular cell at the upper end of the boring above the last stored cell, and capped this by a long plug of pith particles. In the one nest in which the vestibular cell and closing plug were still present, the cell was 53 mm long; the plug was 30 mm long and ended 13 mm below the cut end of the stem. In the other nests there was just an empty space of varying length above the last provisioned cell. However, I had broken off the ends of these stems to determine whether each held a nest, and the closing plugs were lost during this process. Apparently the vestibular cell must always be fairly lengthy, because there were empty spaces of 25 to 53 mm above the last provisioned cell in each of these nests.

The number of provisioned cells per nest ranged from 3 to 12 (mean 7.5). There were no notable variations in nest architecture in the six nests except for the differences in length of the cells and of the partitions closing them. The opened nest had a somewhat moniliform appearance. The cells were somewhat wider than the pith partitions because the pith opposite each cell was chewed out to provide pith particles for the partition capping the preceding cell.

I did not obtain much data on the life history. The wasps overwintered as resting larvae, and adults emerged the following spring about the middle of May. Occupants of all of the cells were resting larvae or newly transformed adults when I opened the nests for study.

The cocoons, which were covered with prey remains, were very light tan and fusiform in shape with a small pore at the anterior end. Four cocoons, from which two females emerged were 7 to 8 mm in length; ten male cocoons were 6 to 8 mm long. The cocoons were always oriented with the anterior end upward toward the nest entrance.

There are undoubtedly at least three generations a year, because I have collected adults at Plummers Island from 17 May to 17 October.

In individual overwintering nests having five or more occupants, adult emergence required 12 to 20 days. Under laboratory conditions five males emerged from one nest 22 March to 10 April, while a single female emerged 3 April; a male had emerged from the outermost cell of this nest on 5 August the preceding summer. In another nest four males emerged 28 March to 3 April and a single female on 8 April. In the third nest six males emerged 21 March to 4 April and a lone female on 3 April.

I reared 5 females and 20 males from 45 provisioned cells. The sequence of sexes in the nest is probably usually random, as may be seen from the following table of the three nests from which both sexes emerged (*x* indicates mortality):

	1	2	3	4	5	6	7	8	9	10	11	12
8362 L	♀	♂	♂	♂	♂	♂	♂	*x*				
9962 G	♀	♂	♂	*x*	♂	♂	*x*	*x*	*x*	♂	*x*	*x*
9962 H	♂	♂	♂	♀	♂	♂	♂					

The prey of this species consisted of midges. The midges contained in the one cell which I preserved were 1.7 to 4.2 mm long, and there were more males than females. These midges were identified as follows:

Ceratopogonidae
  Palpomyia subasper (Coq.)—9
Chironomidae
  Chironomus (*Cryptochironomus*) *fulvus* Joh.—5
  Chironomus (*Cryptochironomus*) *viridulus* (L.)—5
  Chironomus (*Dicrotendipes*) *nervosus* Staeger—1

This species of *Euplilis* is subject to a high rate of parasitism. The occupants of 14 of the 45 provisioned cells were attacked by hymenopterous parasites, and the contents of one additional cell were destroyed by mold. The platygasterid, *Tetrabaeus americanus* (Brues), destroyed the resting larvae in 8 of 26 cells in three nests. The eurytomid, *Eurytoma inornata* Bugbee, parasitized 6 of 11 resting larvae in one nest. I killed a live female eulophid, *Melittobia chalybii* Ashm., on the outside of a wasp cocoon when I opened the nest for study; none of the cells in this nest was parasitized. The highest parasitism rate occurred in an 11-celled nest where *Eurytoma* was reared from cells 1, 2, 5, 6, 8, and 10 and *Tetrabaeus* from cells 3 and 11.

Euplilis (*Corynopus*) *rufigaster* (Packard)

I reared this crabronine wasp from 18 nests, 12 in green stems of *Hibiscus militaris* and 6 in the old dead stems (92361 A, B, E; 101061 E; 8362 E, I, K; 9962 E; 91662 F, G, J, K, P, S, U, V, CC, FF). It is the smallest wasp nesting in hibiscus; reared females were 4–6 mm long. The female wasps entered the pith of the dead stems at the broken or cut upper end of the stems. Those which nested in green stems entered through the entrance boring chewed out by *Ectemnius paucimaculatus*. Most of these *rufigaster* nests were in the empty section of the central cavity above the entrance, but two *rufigaster* females nested in the section below the entrance.

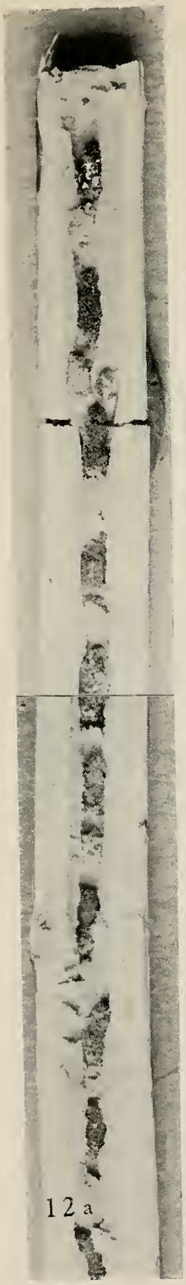
The nest architecture in the dead stems was quite similar to that reported earlier for *Euplilis coarctata modesta*. As in *E. c. modesta*, *rufigaster* used the exposed central cavity in three nests, because there was a basal plug of pith particles 2 to 15 mm thick in three nests at distances ranging from 6 to 18 cm from the broken end of the stem. In the other three nests the wasps either took over an abandoned boring of another insect in the solid pith or chewed out their own straight or sinuous borings; in these nests there was not a basal plug of pith particles. The borings in these latter three stems ended 9 to 20 cm from the broken end of the stem. I did not find an empty vestibular cell in any of these six nests, probably because I had broken off the ends of the stems to determine whether there was actually a nest in each. The diameter of the dead stems was 8.5 to 14 mm. The nest had a moniliform appearance in longitudinal section because the cells were barrel-shaped with a minimum width of 3 mm, and the plugs capping them had a width of only 2 mm. There were 4 to 16 cells (mean 8 cells) in the six nests in dead stems.

In the green stems, where *rufigaster* nested above the *paucimaculatus* entrance, the female usually constructed the first cell at the upper end of the central cavity, or else chewed out a somewhat sinuous boring above the termination of the central cavity. In one nest the wasp did not use the uppermost part of the central cavity, but built a short plug 64.5 cm above the entrance. Then the wasp constructed a series of linear cells working downward toward the entrance, separating adjoining cells by the usual partition of pith particles (Fig. 12). Usually there was an elongate, empty vestibular cell below the last (lowest) provisioned cell, and finally a closing plug of pith particles at or slightly above the nest entrance. These vestibular cells were 11 to 20 mm long, and the closing plugs were 2 to 30 mm in length. The length of the completed nests in green hibiscus stems was 14 to 72 cm. The cells were usually constructed in a linear series having a moniliform appearance (Fig. 13), but occasionally the cells were set obliquely into the side of the stem (Fig. 14). The cells and their closing partitions were similar in length to corresponding parts of *rufigaster* nests in dead stems.

A dozen cells in which female wasps developed were 5–15 mm long (mean 8.4), while seven male cells were 4–10 mm long (mean 6.9). The pith partitions closing the cells were 1 to 32 mm long (mean 7.4).

The mean number of provisioned cells in completed nests was 7 (range 3–16). However, in two incompleted nests in green stems there were 23 and 26 completely provisioned cells respectively; the 24th and 27th cells were being stored when I picked up the nests. Apparently the egg is not laid until sufficient flies for one cell have been accumulated, because I did not find an egg in any of the partially provisioned cells. However, the egg eventually is laid on one of the flies near the inner (lower) end of the cell (Fig. 18). The flies in a partially stored cell are protected from attack by parasites by a temporary closure of pith particles above the cell (Fig. 15).

In dead stems the cocoons were oriented with the anterior end upward toward the entrance. In green stems where nests were constructed above the entrance, the cocoons were oriented with the head end downward. The only difference in the architecture in these two kinds of nests is that the pith partitions had the smooth concave surface upward in the dead



12 a

12 b

13

14

stems, and downward in the green stems. Therefore, larvae of *rufigaster* probably orient their cocoons with reference to the cell partitions, as do those of the vespid wasps observed by Cooper (1957) rather than with reference to gravity as is probably true of larvae of the hibiscus wasp.

The cocoons are very similar in appearance to those of *coarctata modesta* except for being smaller. They were 4 to 6 mm long with a mean length of 4.6 mm.

There are undoubtedly three or more generations of *rufigaster* annually. I have collected adults at Plummers Island from 19 May to 17 October. Emergence must have taken place earlier than the 19 May date because on that date I collected a female carrying a pale green chironomid. Newly hatched larvae were found in nests as late as 30 September.

I obtained very little information on duration of the immature stages. The wasps overwinter as resting larvae, and adults probably emerge fairly early in May. The pupal stage in the overwintering generation requires about 19 days; it is much shorter during the summer, for in one nest there were resting larvae on 3 August and adults emerged on the 13th.

Emergence of adults from multicelled nests may extend over a considerable period, but sometimes lasts only a few days. For example, nine males emerged from one nest in a 6-day period; in another nest four females emerged in the laboratory from 25 March to 1 April, and seven males from 22 March to 6 April; in still a third nest three females emerged 29–30 March, and nine males emerged 22 March to some date between 12 and 29 April, a period when I was away from Washington. Consequently, emergence from nests of nine cells or more required periods of from 6 to 22 + days.

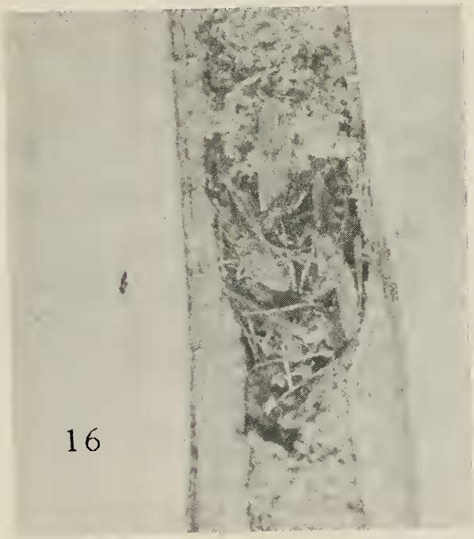
I reared 19 females and 45 males from 158 provisioned cells. The sequence of sexes in the nests is probably a random one as may be seen from the following table (*x* indicates mortality):

	1	2	3	4	5	6	7	8	9	10	11	12
101061 E	*x*	♀	♀	♂	♀							
8362 E	*x*	*x*	*x*	*x*	♂	♀	♀	*x*	*x*	♀	*x*	*x*
91662 J	*x*	♀	♀	♀	♂	♂	♂	♂	♂	♂	♂	♂
91662 U	*x*	♀	♀	♂	♂	♂	♀	*x*	*x*	*x*	♂	*x*

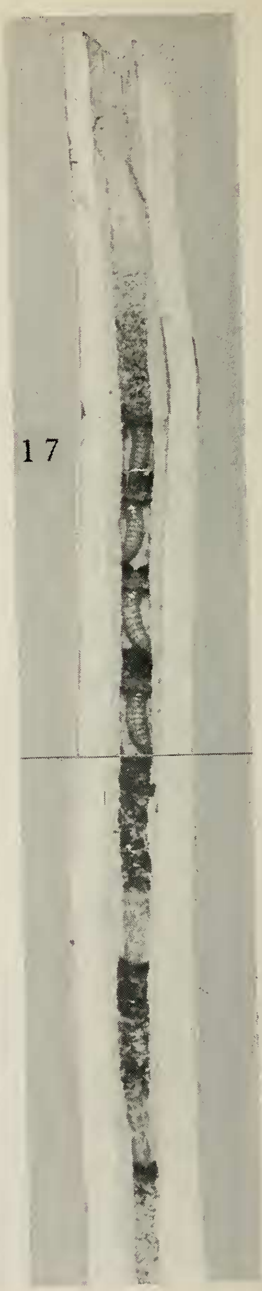
(*Table continued p. 97*)

Plate V. Nests of *Euplilis rufigaster* (Pack.) in green hibiscus stems. Fig. 12, Completed nest 91662 J split open, 18 September 1962, × 1.5; Fig. 12*a*, cells 1–10 (cell 1 at top); Fig. 12*b*, cells 11–16 (cell 11 at top) and entrance hole (10 mm above the 12*b*) of hibiscus wasp which was used by the *Euplilis* as its nest entrance also; note that boring is sinuous and that some cells are in a linear series, others individually in pockets off the main boring. Fig. 13, Cells 5–6, nest 91662 U, contents removed, showing cells in linear series, 20 September 1962, × 3.0. Fig. 14, Cells 23–24, nest 91662 U, contents removed, showing cells in pockets on side of main boring, 18 September 1962, × 3.4.

15



16



17

18

	13	14	15	16	17	18	19	20	21	22	23
101061 E											
8362 E	*x*	*x*	*x*	*x*							
91662 J	♂	♂	♂	♂							
91662 U	♂	*x*	♂	*x*	♂	*x*	♀	*x*	*x*	*x*	*x*

E. rufigaster, like *coarctata modesta*, preys entirely on midges. However, I have no records of its using anything but Chironomidae. I preserved the prey from eight completely or partially provisioned cells. Consolidated prey records from these five nests are as follows:

Gen. and spp.—10
Orthocladiinae (gen. and sp.)—18
Cricotopus sp.—4
Chironomus (*Cryptochironomus*) sp.—4
Chironomus (*Cryptochironomus*) *fulvus* Joh.—12
Chironomus (*Cryptochironomus*) *nigrovittatus* Mall.—9
Chironomus (*Cryptochironomus*) *viridulus* (L.)—91
Chironomus (*Dicrotendipes*) *nervosus* Staeger—4
Chironomus (*Xenochironomus*) *xenolabis* (K.)—17
Tanytarsus sp.—22

One nest of an *Euplilis* species (92863 B) in a dead stem was probably that of *rufigaster*, because the two completed cells, both containing eggs which failed to hatch, were 6–7 mm long. Cell 1 contained all Chironomidae except for one tipulid, *Polymeda cana* (Wlkr.), and incompleted cell 3 contained all Chironomidae except for one ceratopogonid, *Bezzia setulosa* (Lw.).

The number of midges stored per cell varied according to their size (Fig. 16). There were 50 midges 0.9–3.6 mm long in one cell and 29 midges 1–5 mm long in another cell. Both sexes of midges were stored in each cell, but the majority were males. Usually three to five species were stored per cell. All of the prey reported above were from nests stored during September; undoubtedly nests provisioned earlier in the season would be stored with other species.

Several years ago (Krombein, 1958) I published a few brief notes on a population of *rufigaster* nesting in deserted anobiid borings in the porch steps of the cabin at Plummers Island. These *rufigaster* used the following chironomids in the period 22 August–20 September 1957: *Chironomus nervosus* Staeger, *C. modestus* Say, *C. neomodestus* Mall., *Procladius*

PLATE VI. Nests of *Euplilis* sp. and *Pemphredon lethifer* form *littoralis* Wagn. in dead hibiscus stems. Fig. 15, Partially stored cell 3, nest 8362 J, *Euplilis* sp., 5 August 1962, × 4.0; note loose partial plug of pith particles above midges and no wasp egg. Fig. 16, Completely stored cell, unnumbered nest, *Euplilis* sp., 12 July 1962, × *ca.* 5.0. Fig. 17, Completed nest 72763 B, *Pemphredon lethifer* form *littoralis*, 27 July 1963, × 1.3; note wasp pupae in cells 1 and 3, aphids and interspersed pith particles in cells 2 and 4, wasp prepupae in cells 5–8. Fig. 18, Female midge, *Chironomus fulvus* Joh., with egg of *Euplilis* sp. between head and forelegs, cell 1, nest 92863 B, 29 September 1963, × 7.3.

culiciformis (L.), *Calopsectra* sp., *Cricotopus* sp., and several species belonging to unknown genera and species. One wasp required 5 minutes to leave her nest, capture a midge, and return to the nest with it. The prey is carried beneath the wasp while in flight, venter to venter, and head end forward.

E. rufigaster apparently is not as subject to parasitism as is *coarctata modesta*.[4] Of 158 provisioned cells the occupants of only 13 were destroyed by parasites, 8 by mold, and 2 were attacked from the outside of the stem by an unknown predator. The eurytomid, *Eurytoma inornata* Bugbee, parasitized 6 of 10 cells in one nest. The platygasterid, *Tetrabaeus americanus*, destroyed the resting larvae in 3 of 30 cells in two nests; I found a live female in each of two other nests but neither was successful in parasitizing any of the wasp larvae. The torymid, *Diomorus zabriskiei* Cresson, parasitized one cell in a 5-celled nest. One maggot of the sarcophagid fly, *Ptychoneura aristalis* (Coquillett), fed on the prey in three cells in a 13-celled nest in order to reach maturity. Only one species of parasite occurred in each of the parasitized nests.

Trypoxylon (*Trypoxylon*) sp. or spp.

One cell of this sphecid wasp (or wasps) occurred in hibiscus stems, one in a green stem (91662 I) and two in dead stems (8362 L, 9162 T). The nest in the green stem consisted of a single cell 9 cm above the entrance to an *Ectemnius paucimaculatus* nest which was entirely below the entrance. The cell was 15 mm long, and had a clay partition at each end. The *Trypoxylon* larva was spinning its cocoon on 16 September 1962, when I opened the nest; the larva died a few days later. In the second nest (8362 L) the *Trypoxylon* made a 1-mm clay seal 17 cm below the cut end of the dead stem; its single cell was 35 mm long. It contained a mature larva on 3 August 1962, which died a few days later. The third nest (9162 T) consisted of a cocoon in a single cell in a preexisting boring in the cut end of a dead stem. There was a pupa in this cocoon on 5 September 1962 from which a female *Eurytoma inornata* Bugbee emerged on 10 September. There were two cells in still another nest (82863 A) in a dead hibiscus stem with a diameter of 11 mm. The nest boring was 3 mm wide. There was a clay seal 1 mm thick 66 mm below the entrance in the broken end of the stem. Cell 1 was 20 mm long and contained an empty cocoon from which the *Trypoxylon* emerged prior to 28 August. The second cell was 46 mm long and contained a *Trypoxylon* cocoon in which there was a live ichneumonid pupa; this parasite died a few days later. It was identified as a species of *Messatoporus*, probably *rufiventris* Cush.

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[4] It is quite possible that the actual parasitism rate for *rufigaster* is much higher. I had 20 additional *Euplilis* nests, presumably stored mostly by *rufigaster* and some by *E. c. modesta*, from which I was unable to rear wasps. Many of these nests were quite heavily parasitized by *Tetrabaeus americanus*; other parasites in them were *Perilampus canadensis*, *Eurytoma inornata*, *Habritys latro* Wallace and *Eustalomyia vittipes*.

In Japan, *Trypoxylon obsonator* Smith occasionally uses the empty sections of nests of *Ectemnius rubicola nipponis* Tsuneki as a nesting site; a similar relationship does not appear to occur as commonly between the hibiscus wasp and species of *Trypoxylon*.

Pemphredon (*Cemonus*) *lethifer* form *littoralis* Wagner

Although this pemphredonine wasp, an adventive from Europe, is reasonably common along the margin of the river, I found only one nest (72763 B, Fig. 17). It was in the upper 12 cm of a boring in the broken end of a dead hibiscus stem 13 mm in diameter. At the lower end of this boring was a plug of fine pith particles 10 mm thick, which sealed off an old *Euplilis* nest beneath. The boring occupied by the *Pemphredon* had a diameter of 3 to 3.5 mm.

I found and opened the nest the morning of 27 July. At that time there was a female wasp pupa in the innermost cell and five wasp prepupae in other cells. By that evening one of the prepupae had pupated, and three others pupated the next day; I crushed the fifth one when I closed the split halves of the stem.

There was a series of eight linear cells in the nest, measuring respectively from the innermost 10, 10, 9, 11, 9, 9, 9 and 8 mm in length. Apparently eggs failed to hatch or were absent in the areas which formed cells 2 and 4; these cells contained approximately 100 aphids, mostly nymphs but a few winged adults of *Chaitophorus populicola patchae* H. R. L., and many interspersed fine particles of pith. The other cells did not contain any loose pith particles, but were sealed above by a convex, silken cap, the vestigial cocoon. Each of these silken caps had fine pith particles covering the upper, outer surface. From these data it is reasonable to assume that the mother wasp does not construct partitions between the cells, but merely stores a number of aphids and interspersed fine particles of pith and lays an egg at intervals of about 10 mm. The larvae cannot be cannibalistic. When they reach maturity and are ready to spin cocoons, each one must compact the loose pith particles at the lower end of the cell, void the meconial pellets, spin a silken partition over them, and then spin a silken cap at the upper end against the layer of pith particles at the bottom of the adjacent cell.

Above the eighth cell was a plug of loose pith particles 15 mm thick. The upper 20 mm of the boring were empty and wider than in the provisioned part of the nest. A wasp flew out from this upper empty space when I picked up the stem. About 10 minutes later I captured a female *Pemphredon lethifer* as she hovered in the air in approximately the area where the nest opening had been. I think this was the same wasp that escaped earlier, although its appearance in the area might have been fortuitous. Rau (1948) mentioned that a *lethifer* female continued to use the vestibule of a recently completed nest as a home, while she started another nest in an adjacent stem.

A female wasp emerged from cell 1 on 1 August. From the remaining cells one male emerged on 5 August and two females on 6 August; a male pupa died. It is not possible to present data on the arrangement of sexes in the nest, except for cell 1, because the prepupae in cells 3, 5, 6, 7, and 8 fell out and were mixed when I split open the nest.

Several years ago (Krombein, 1958) I found two nests of this wasp in borings in sumac pith. In one nest, in which larvae were feeding, there were no partitions between the cells. This wasp had stored nymphs of a species of *Aphis*. Earlier still Rau (1948) reported this species (as *inornatus* Say) as nesting in hollow stems of *Weigelia* and provisioning with *Aphis gossypii* Glov. He reported that the cells were 6.3–9.5 mm long; presumably these measurements included the cap for each cell.

Janvier (1960) published a detailed account of the biology of French populations of *P. lethifer* form *littoralis* under the name *unicolor* (Panzer). His description of the nest architecture differs in an important detail from the nest I found in hibiscus and those which I described earlier (Krombein, 1958) from sumac. He reported that the mother wasp capped each cell by a plug of pith particles from one to several millimeters thick, whereas I found that the mother did not make partitions between the cells but scattered bits of pith among the aphids. J. de Beaumont examined the wasps reared by both Janvier and myself, and reports that they are both *lethifer* form *littoralis*. Tsuneki (1952) stated that Ohgushi found nests of *lethifer* form *fabricii* (Müller) in Japan in which there were no separating partitions except in the outermost cells, so that for considerable lengths of the nests there were numerous aphids with eggs or young wasp larvae at intervals. Ohgushi apparently did not mention whether pith particles were interspersed among the aphids, but he reported that there was no cannibalism among the wasp larvae. L. Chandler (personal communication) wrote me that one of his students, working on nesting populations of *lethifer* in sumac in Indiana, found a gradation from nests with extremely long partitions of pith particles between the cells to those with very flimsy partitions or none at all.

PARASITES AND PREDATORS OF THE HIBISCUS WASP AND ITS ASSOCIATES

This hibiscus wasp and its associates, particularly the two crabronine wasps, *Euplilis coarctata modesta* and *E. rufigaster*, are subject to attack by at least a dozen parasites. These include seven species of Hymenoptera, five of Diptera, and one of Acarina. Five of the hymenopterous parasites are chalcidoid wasps, one is an ichneumonid wasp, and one is a proctotrupoid wasp. Of the dipterous parasites, all except *Megaselia* are muscoid flies, either Sarcophagidae or Anthomyiidae. Properly speaking, the *Megaselia* is not a parasite but a scavenger. However, the evidence is rather convincing that its presence in a cell may result in destruction of the host egg or young larva before it begins to feed as a scavenger on the prey stored for the wasp larvae. In the aggregate, except for the mite *Vidia cooremani* Baker, which is a symbiont, these parasites exact a very substantial toll on the eggs or larvae of the wasps.

Messatoporus rufiventris Cushman (?)

I found a live pupa of *Messatoporus* inside the cocoon of a species of *Trypoxylon* (*Trypoxylon*) in a nest in a dead hibiscus stem (82863 A) on 28 August 1963. This pupa died several days later after nearly attaining adult coloration. H. K. Townes was able to place the pupa definitely as a species of *Messatoporus*, and remarked that the color pattern, as so far developed, resembled that of *rufiventris* Cush., rather than the other two species occurring in the United States.

Townes and Townes (1962) reported several rearing records for *rufiventris* from mud cells of the pompilid wasps, *Auplopus* sp. and *Phanagenia bombycina* (Cr.). They remarked that all species of the genus are probably parasitic in nests of mud wasps. The present rearing record extends the host range considerably, but it does not contradict the Townes' prediction that *Messatoporus* parasitizes mud wasps. *Trypoxylon* (*Trypoxylon*) constructs mud partitions between the cells in its nest. It also preys on spiders, although it stores a number of spiders in each cell rather than just one as in the pompilid wasps.

Melittobia chalybii Ashmead

I found a live female of this eulophid wasp in each of two nests (9962 H, 72763 C). One of them was on the outside of a cocoon containing a viable resting larva of *E. coarctata modesta* on 9 September 1962. The other was found in a cell containing a newly hatched larva of a species of *Euplilis* on 27 July 1963. In neither case had the *Melittobia* parasitized any the nest occupants. This eulophid is a very serious parasite of resting larvae or pupae in laboratory cultures; I have found it quite commonly in wooden trap nests of solitary wasps. All the evidence indicates that in nature it attacks primarily resting larvae of wasps in mud cells or in borings in wood, although there are many records of its having been reared from insects other than wasps; however, probably most of these cases occurred in laboratory cultures. Schmieder has discussed the biology very thoroughly in a series of excellent papers (see Muesebeck *et al.*, 1951, for references).

Perilampus canadensis Crawford

This perilampid wasp was reared from one cell each in six nests of the hibiscus wasp containing 3 to 18 cells (72162 C; 72862 E; 9162 G, P; 91662 S, Y) and from one cell in a 10-celled nest of an *Euplilis* sp. (9962 D).

The exact method by which the parasite gains access to the nest is not known. However, if the behavior of *P. canadensis* is similar to that of other *Perilampus* species, we can expect to find the eggs deposited on leaves. The *Perilampus* planidium (first-instar larva) may attach itself to the wasp, or even to one of the flies used as prey before its capture by the wasp, and then be carried into the wasp nest. Once in the nest, the planidium may attach itself to the newly hatched host larva. At any rate the *P. crawfordi* planidium must attach itself to the mature wasp larva so that it is encased in the cocoon spun by the latter. In every case the adult *Perilampus crawfordi* emerged from the wasp cocoon. In one cell I observed the *Perilampus* larva feeding on a pupa of the hibiscus wasp on 29 July; a male *Perilampus* emerged 13 August, about 10 days after one would have expected the host wasp to emerge as an adult.

In an earlier paper (Krombein, 1960) I recorded *P. canadensis* as parasitizing *Ectemnius* (*Hypocrabro*) *stirpicola* (Pack.) in nests in sumac pith. In each of two nests only one cell of several was parasitized by the *Perilampus*. The rearing records for this species of *Perilampus* from a fly, *Zenillia* sp., and from a sawfly, *Macremphytus* sp., given in Muesebeck *et al.* (1951), are probably erroneous (*teste* B. D. Burks, personal communication).

Diomorus zabriskiei Cresson

This torymid wasp is also of secondary significance as a parasite. I reared it from six nests of the hibiscus wasp (91662 X, Y, EE, II; 61663 T, X) and from one nest of *Euplilis rufigaster* (91662 S). One male emerged from one cell of the 6-celled nest of *rufigaster.* It was a more successful parasite of the hibiscus wasp; 4 females and 7 males emerged from 51 cells in the six nests which *Diomorus* attacked. Only one cell was parasitized in each of three nests; in the other nests there were two parasitized cells each in 8- and 18-celled nests, and four parasitized cells in a 12-celled nest. In the nests in which several parasitized cells were found, the arrangement of cells was as follows: (D = *Diomorus*; T = *Tetrabaeus*; W = wasp; P = *Perilampus*; *m* = moldy; *x* = dead; M = *Megaselia*).

	1	2	3	4	5	6	7	8	9
91662 X	♂D	*m*	♀D	♂D	♂D	T	T	*m*	M
91662 Y	♀W	♀W	*m*	♂P	♂W	♀W	*m*	*m*	*m*
91662 II	M	T	*m*	♂W	♂D	♂W	♀D		
	10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
91662 X	T	T	T						
91662 Y	*m*	*m*	*m*	♂D	*x*	*x*	♀D	*x*	*m*
91662 II									

These data suggest that the female *Diomorus* may occasionally parasitize several cells in succession. Inasmuch as this female parasite has a rather long ovipositor, it is assumed that parasitism may take place through the stem wall.

The *Diomorus* is parasitic on the resting larva of the wasp within its cocoon. The full-grown larva of the parasite has long hair. Adults of

Diomorus emerged in the spring at the same time that adult wasps were emerging from adjacent cells. However, in the nests of the summer generation of wasps, the parasites emerged about 12 days after the wasp. In one cell the *Diomorus* larva was full grown on 3 July, pupated on 5 July, and the adult emerged on 18 July.

Earlier (Krombein, 1960) I recorded *D. zabriskiei* as a parasite of *Ectemnius* (*Hypocrabro*) *stirpicola* (Pack.) in nests in sumac twigs. Several cells were parasitized in each of two nests.

Habritys latro Wallace

A few years ago I noted (Krombein, 1960) that this pteromalid wasp was the most successful parasite of the crabronine wasp, *Ectemnius* (*Hypocrabro*) *stirpicola* (Pack.), in nests in sumac twigs. I found *latro* in only one nest of a species of *Euplilis* in a dead hibiscus stem (9962 D). A dead *latro* female was attached to the outer cocoon wall of the wasp in cell 3 from which a number of *Tetrabaeus* emerged later, and another female was found in the incompletely provisioned cell at the outer end of this nest. I found earlier that the *latro* female deposits 6–12 eggs on the resting larva of the *stirpicola*.

Eurytoma inornata Bugbee

This eurytomid species was described (Bugbee, 1962) from a series which I reared during the course of this study on the hibiscus wasp and its associates. It parasitized five nests in dead hibiscus stems (92361 D, F; 9162 T; 9962 E, F), one each of *Euplilis rufigaster* and *E. coarctata modesta*, two of a species of *Euplilis* (either or both of the species named earlier), and one of a species of *Trypoxylon* subg. *Trypoxylon*. The two species of *Euplilis* are undoubtedly the normal hosts for *inornata*, because I obtained 11 females and 5 males from 26 provisioned cells in the four *Euplilis* nests. There was only a single cell in the *Trypoxylon* nest, from which I reared a female *Eurytoma*. The sequence of cells in the three nests which contained more than one cell was as follows: (E = *Eurytoma*; T = *Tetrabaeus*; W = wasp, the sex also being indicated by the appropriate sign where there was no prepupal mortality; x = dead from mold)

	1	2	3	4	5	6	7	8	9	10	11
92361 F	♀E	x	♂E	♀E							
9962 E	♂E	W	W	W	♀E	♂E	♂E	♂W	♀E	♀E	
9962 F	♀E	♀E	T	♂W	♀E	♀E	♂W	♀E	♂W	♂E	T

It seems probable that the *Eurytoma* parasitizes the wasp cells by inserting the ovipositor through the stem. The *Eurytoma* larva feeds on the resting larva of the wasp.

All of the *Eurytoma* were reared from overwintering nests. However, it must parasitize nests of the wasps throughout the season, because the adult *Eurytoma* usually emerged early in the spring, at the same time as wasps from adjacent cells. However, this is not always true. In nest 9962 E the wasps in cells 2–4 emerged prior to 9 September and the *Eurytoma* in cell 10 emerged 18–20 September; occupants of the outer cells, including the rest of the *Eurytoma*, emerged the following spring. Also, the *Eurytoma* in the *Trypoxylon* cocoon (9162 T) emerged 10 September. In the laboratory a female *Eurytoma* emerged 3 April from one cell; it was a pale pupa on 16 March or earlier. In the field I netted a male *inornata* on 2 June 1963 in a clump of hibiscus, and a female *inornata* similarly on 22 July 1962.

Tetrabaeus americanus (Brues)[5]

This tiny (♀, 1.2 mm long) platygasterid wasp is the most effective parasite of the several crabronine wasps nesting in green or dead stems. I recovered or reared it from 26 nests,[6] 14 of them in green stems and 12 in dead stems. Nine of the nests containing this parasite in green stems were those of the hibiscus wasp, three of *Euplilis rufigaster* and two of *Euplilis* sp., quite possibly *rufigaster*. In the dead stems, three of the nests containing the parasite were of *E. coarctata modesta*, one of *E. rufigaster* and eight of *Euplilis* sp., undoubtedly either of the two preceding species.

In six nests, I found either a live or dead female *Tetrabaeus*, but no parasitized cells. I found three dead females, two in the partition of pith particles capping cell 3 in a 3-celled nest, and the other in a partition capping cell 2 in a 4-celled nest. I recovered four live females, one in each of four nests, in or alongside the partition capping one of the cells.

The female *Tetrabaeus* gains access to the host nest either while the latter is being constructed or after it has been completed. The parasite can easily dig out a tiny tunnel alongside or through the partitions of pith particles capping the cell. Apparently she usually travels downward in the stem depositing her eggs in the host egg or larva in each of several cells in turn. Occasionally, one or several healthy wasp larvae will be found between two parasitized cells; so either the *Tetrabaeus* female fails to oviposit in all of the cells, or perhaps not all of her eggs are viable, or possibly the cells are parasitized by two different females. I do not know what stage of the wasp she attacks, but I judge that it must be either the egg or young larva because I have found females of *Tetrabaeus* in incompletely or recently provisioned nests. Regardless of the stage attacked the wasp larva is able to reach maturity and spin its cocoon

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[5] This species was described by Muesebeck (1963) as a new genus and species, *Crabroborus krombeini*, from material reared during this study. Subsequent examination of type material of *Tetrabaeus americanus*, placed erroneously in Scelionidae by Brues, demonstrated that the two species are conspecific. Brues' type series was reared from crabronine cocoons collected in Wisconsin by Barth.

[6] The account presented here is based on nests 9861 A; 92361 A, E, H; 10761 A, B, C; 8362 A, G; 9162 D, N; 9962 C, D, F, G; 91662 D, J, L, R, S, U, X, DD, EE, II; 61663 I.

before the developing parasites destroy it. Clancy (1944) noted that the platygasterid *Allotropa burrelli* Mues. parasitized all nymphal stages of its coccid hosts.

I did not make any observations on the earlier larval stages of the parasite; presumably it may have only one instar as has been reported for other platygasterids. When the numerous parasite larvae are mature, each one forms a hard, transparent, capsulelike cell, distending the host epidermis (Fig. 11*a*). The host mummy bears a superficial resemblance to that of the lepidopterous *Gnorimoschema* attacked by the polyembryonic encyrtid *Copidosoma*. However, the *Tetrabaeus* cannot be polyembryonic, because at least a few males were obtained from nearly every parasitized wasp larva.

The parasites pupate within the individual cells inside the host. The exact length of the pupal stage is unknown; but it may require 12–15 days, because adults emerged in 7–10 days from cells containing black-eyed pupae. In one nest there were black-eyed pupae on 2 October; on the next day several showed some darkening of the body, and all pupae were dark on 4 October. The first adults eclosed on 6 October. The first adults to leave the cells did so on 8 October. Emergence from a single host mummy usually required 2 to 3 days, although rarely a few stragglers emerged 7–10 days after their siblings.

Emergence of the parasites was not always synchronized with that of the host wasps. In the only parasitized, first-generation hibiscus wasp nest, the *Tetrabaeus* emerged 10–12 days after the single wasp emerged 6 July. In four nests provisioned by the hibiscus wasp and the two species of *Euplilis*, the *Tetrabaeus* emerged in September and October, while wasps from adjacent cells in these nests did not emerge until the following spring. In another five nests provisioned by the hibiscus wasp and by *E. coarctata modesta*, the *Tetrabaeus* emerged in the spring concurrently with the host wasps. It is presumed that the *Tetrabaeus* emerging in the fall may parasitize other nests that same season. If they can overwinter successfully as adults, which is not at all certain, nests would not be available for them to parasitize before the middle of May. Clancy (1944) stated that the adult platygasterid *Allotropa* usually lived no more than 10 days. If *Tetrabaeus* adults are equally short-lived, they certainly could not overwinter and parasitize nests the following spring. Clancy found that *Allotropa* overwintered as resting larvae.

In three other nests provisioned by the hibiscus wasp, by *E. coarctata modesta* and by *Euplilis* sp., there was divided emergence. *Tetrabaeus* emerged from some cells in the fall and from other cells in the spring, and the wasps emerged in the spring only. In the single nest of the hibiscus wasp, *Tetrabaeus* emerged from cells 10–12 in September and from cells 6 and 7 the following spring. In the nest of *E. coarctata modesta*, the *Tetrabaeus* emerged from cells 4 and 7 about 18 September, from cell 8 between 19 and 28 September, and from cells 11 and 12 the following spring. In the *Euplilis* nest, *Tetrabaeus* emerged from cell 3 in September and from cell 1 the following spring. The evidence is rather confusing. Apparently, a single female began parasitizing cells in the *E. coarctata modesta* nest from near the inner end and gradually worked her way toward the entrance; or, perhaps one female may have parasitized cells 4, 7 and 8 and a second female parasitized cells 11 and 12. In the other two nests the mother *Tetrabaeus* must have worked her way from the outer cells toward the inner, unless two females entered each nest.

The following table presents data on the number and sex of *Tetrabaeus* cells found in each infested larva. The nests above the first cross rule are those of the hibiscus wasp; those above the second rule are *Euplilis coarctata modesta*; those above the third rule are *Euplilis rufigaster*; those in the lowest section of the table are *Euplilis* sp., probably both of the preceding species. The number of reared *Tetrabaeus* does not always equal the total number of parasite cells found in the larva. This results from two factors: first, some of the parasites emerged and escaped before I opened some nests; and second, parasites did not mature in some of the cells in the host larva.

Nest and cell	Number of reared *Tetrabaeus*	Number of *Tetrabaeus* cells per infested larva	Range and mean number of parasites per host larva
9162 D, cell 1	22♀, 1♂	28	
9162 D, cell 2	17♀, 2♂	19	
91662 R, cell ?	?	?	
91662 R, cell ?	26♀, 3♂	29	
91662 R, cell ?	?	?	
91662 S, cell 4	21♀, 2♂	23	
91662 X, cell 6	25♀, 1♂	26	Range: 17–32
91662 X, cell 7	15♀, 2♂	17	Mean: 24.7
91662 X, cell 10	?	?	for *Ectemnius*
91662 X, cell 11	?	?	*paucimaculatus*
91662 X, cell 12	?	?	
91662 DD, cell 2	24♀, 2♂	26	
91662 DD, cell 4	23♀, 2♂	25	
91662 EE, cell 6	20♀	23	
91662 II, cell 2	28♀, 1♂	32	
61663 I, cell 1	23♀, 2♂	29	
61663 I, cell 3	12♀, 2♂	19	
9962 C, cell 1	11♀, 1♂	12	
9962 F, cell 3	8♀, 2♂	10	
9962 F, cell 11	7♀, 1♂	8	Range: 3–23
9962 G, cell 4	10♀, 1♂	11	Mean: 11.4
9962 G, cell 7	20♀, 3♂	23	for *Euplilis*
9962 G, cell 8	13♀, 1♂	14	*coarctata modesta*
9962 G, cell 11	8♀, 2♂	10	
9962 G, cell 12	3♀	3	

(Continued)

Nest and cell	Number of reared *Tetrabaeus*	*Number of Tetrabaeus* cells per infested larva	Range and mean number of parasites per host larva
92361 A, cell 4	?	14	Range: 11–14 Mean: 12.5 for *Euplilis rufigaster*
92361 A, cell 5	?	?	
91662 U, cell 9	5♀	11	
92361 H, cell 1	14♀	15	
92361 H, cell 2	8♀	15	
92361 H, cell 3	16♀	25	
10761 A, cell 1	?	15	
10761 A, cell 2	?	15	
10761 A, cell 3	?	22	
10761 A, cell 4	18♀, 2♂	20	
10761 A, cell 5	15♀, 3♂	18	Range: 6–25
10761 B, cell 1	?	18	Mean: 15.9
10761 B, cell 2	?	13	for *Euplilis* spp.
10761 B, cell 3	?	16	
10761 B, cell 4	?	22	
10761 B, cell 5	?	?	
9162 N, cell 1	7♀, 1♂	11	
9162 N, cell 2	5♀, 1♂	6	
9962 D, cell 1	13♀, 1♂	14	
9962 D, cell 3	8♀, 2♂	15	
91662 L, cell 11	6♀, 4♂	10	

As expected from their larger size, the parasitized larvae of the hibiscus wasp yielded more parasites than did the smaller species of *Euplilis*. This was not necessarily because more eggs may be deposited in an hibiscus wasp egg or larva. In his study of the platygasterid *Allotropa burrelli*, Clancy (1944) found definite evidence of cannibalism, which he attributed to chance encounter rather than to aggressive action on the part of the parasite. It seems to me that cannibalism in both of these platygasterid species is more likely to occur when more parasite larvae are present than can reach maturity on the host tissues. If cannibalism occurs in *Tetrabaeus*, it is probably more prevalent in *Euplilis* larvae than in *Ectemnius* larvae because of the smaller size of the former.

I obtained 451 females and 45 males from a total of 682 *Tetrabaeus* cells in 39 parasitized larvae of these three crabronine wasps, giving a sex ratio of 10:1. Clancy reported a sex ratio of 2.7:1 for Japanese material of *Allotropa burrelli* and of 2:1 for laboratory-reared material in New Jersey.

Euplilis rufigaster is smaller than *E. coarctata modesta* and one would expect to obtain fewer *Tetrabaeus* from a *rufigaster* larva. The fact that the mean number of *Tetrabaeus* obtained from *rufigaster* was larger than the mean number reared from *coarctata modesta* was probably due to too few rearings from the former host. In this connection, it can be stated that nests 9162 N and 91662 L, from which no wasps were reared, were almost positively nests of *rufigaster* because they were in green hibiscus stems. If we average the *Tetrabaeus* obtained from those two nests with those from nests 92361 A and 91662 U, we obtain a range of 6 to 14 parasites per *rufigaster* larva and a mean of 10.4.

Earlier in this project I assumed that *Tetrabaeus* had only the two species of *Euplilis* as hosts, because I reared it from them only in the 1961 nests. However, the 1962 nests of the hibiscus wasp yielded a large number of *Tetrabaeus*. *Tetrabaeus* parasitized 17 of 56 cells in eight nests of the hibiscus wasp, 8 of 26 cells in three nests of *coarctata modesta*, 3 of 30 cells in two nests of *rufigaster*, and 18 of 30 cells in six nests of *Euplilis* spp. Perhaps, after studying many more nests, we may eventually find that *Tetrabaeus* will attack other wasps than Crabroninae nesting in hibiscus.

Inasmuch as the summer generation of *Tetrabaeus* requires 10–12 days more than the host wasps to reach maturity, it seems probable that there are no more than two complete generations annually with possibly a very small third generation.

Megaselia aletiae (Comstock)

This phorid fly is one of the more serious enemies of the hibiscus wasp. I have never found it in nests of the other hibiscus-nesting wasps, even those of *Euplilis rufigaster* which occasionally nests in green hibiscus stems. The fly usually acts as a scavenger, but it is probable that the activities of its larvae in a newly provisioned cell will destroy the wasp egg, and it is certain that the invasion of other wasp cells by *Megaselia* larvae results in the death of the wasp larva in each cell. I reared *aletiae* adults from seven nests (101061 A; 71162 C, E; 72162 C; 91662 H, Q, GG). In addition, *Megaselia* sp., undoubtedly *aletiae*, was noted or reared from 17 other nests (101061 B; 71162 G; 72862 B, C, E; 91662 I, R, CC, DD, EE, HH, II; 61663 E, I, K, R, X; 72163 A). Altogether, these phorids destroyed 30 of 93 provisioned cells in 18 nests.

The phorid female is a very brazen animal. Twice, while I watched females of the hibiscus wasp gnaw out entrances in hibiscus stems, a female phorid was quite persistent in trying to get into the incompleted entrance boring. In one case (72862 C) the persistent investigation by the phorid drove the wasp off. Later, in this same nest, the phorid was still attending the wasp, occasionally crawling beneath the wasp's legs; but the wasp did not again take alarm from the phorid's activity. In the other nest (72862 E), another phorid attended the wasp very persistently while she gnawed at the burrow entrance. Subsequently, when these nests were opened a week later, I did not find any infestation by phorids.

Except in one nest, the phorids attacked cells below the entrance; in this other nest, *aletiae* infested one of two cells *above* the entrance. In several nests infested by phorids the wasp constructed one or more empty intercalary cells above the infested section. These empty cells may have been a device preventing infestation of later cells by maggots from the earlier cells.

I have no data on the early stages of infestation by *aletiae*. Presumably the mother deposits eggs or young larvae in the cell, or at least inside the central cavity of the stem. The larvae, at least older ones, can wriggle through the fine pith particles capping the partitions. The larvae feed on the decomposing prey stored by the hibiscus wasp. If there is insufficient nourishment in the first cell infested, they migrate into adjacent cells. Pupation takes place within the cells where the larva reaches maturity. In one nest, adult flies emerged in July, 11 days after the puparia were formed; in another nest in late September, the period in the puparium lasted 15 days. Flies may emerge as much as a week earlier than wasps in the same nest, or as much as two days later than the wasps. In one nest (72162 C) several newly eclosed adult *aletiae* left the nest when I opened it on 24 July. On this same date there were some full-grown phorid larvae in the same nest. This is an indication that deposition of phorid eggs or larvae may take place over a lengthy period. The nests, of course, are rather poorly protected from attack by phorids. Even in a completed nest, the phorid female can gain the central cavity through the entrance boring, oviposit or deposit larvae on the closing plug, and the phorid larvae can then bore through the pith particles until they reach the cells.

Macronychia aurata (Coquillett)

I reared this sacrophagid fly only once from a nest of the hibiscus wasp (72162 C). This was a 9-celled nest with all cells below the entrance hole. The maggot fed on the contents of cells 3–9 and had formed a puparium when I opened the nest on 24 July. The adult fly eclosed on 29 July.

Presumably the mother fly deposits a larva in the entrance hole during provisioning of the nest. The larva wriggles down to the cells and feeds either upward or downward on the prey stored for the wasp.

I have also reared this species of *Macronychia* (Krombein, in press) from a nest of *Ectemnius* (*Hypocrabro*) *continuus* (Fabricius) in a rotton pear limb. These are the only two rearing records for any species of this genus in North America.

Ptychoneura aristalis (Coquillett)

This sarcophagid fly was reared from two nests, both in stems of green hibiscus. One was a 10-celled nest of the hibiscus wasp (9162 K), and the other was a 13-celled nest of *Euplilis rufigaster* (91662 FF). This is a smaller fly than *Macronychia*, and it does not require as much food to reach maturity as does that genus. The maggot in the hibiscus wasp nest fed on the contents of cell 10 only, while that in the *rufigaster* nest fed on the contents of cells 1–3. Both flies had formed puparia by the time I opened the nests in September. A male fly emerged from each of the puparia the following spring, concurrently with wasps from the same nests.

Probably the fly maggot gains access to the nest in the manner suggested for the preceding species.

This is the first host record for this genus of Miltogrammini.

Eustalomyia vittipes (Zetterstedt)

I reared this anthomyiid from seven nests, five of the hibiscus wasp in green hibiscus stems (101061 C; 9162 L; 91662 L, Z, BB) and two of *Euplilis* sp. or spp. in dead hibiscus stems (101061 G, H). Presumably, maggots of this fly gain access to the nest in the same manner as suggested for *Macronychia aurata*. All of the flies were puparia when I opened the nests in September and October.

There were two puparia in each of the two *Euplilis* nests. In one nest the maggots destroyed the contents of cells 1–8 of a 9-celled nest, and in the other they destroyed the contents of cells 3–8 of an 8-celled nest. There were remains of resting wasp larvae in cocoons in four of the cells destroyed in the former nest, so this fly is capable of maturing on wasp larvae as well as on the prey stored for the wasp.

In hibiscus wasp nests, two maggots destroyed both cells in a 2-celled nest, one maggot destroyed two cells in a 12-celled nest, and one maggot destroyed three cells each in a 4-celled and a 5-celled nest. In the fifth hibiscus wasp nest one maggot destroyed one resting larva in a cocoon, and possibly one or more additional cells.

Most of the adult flies emerged in the spring, concurrently with emergence of wasps from adjacent cells. However, in one nest (91662 L), the fly emerged before the nest was opened for examination, and in another nest (101061 G) one of the flies emerged prior to 10 October, when the nest was opened, and the other fly emerged the following spring.

Except in one nest, the maggots infested wasp cells below the nest entrance. When the maggots were full grown they wriggled upward to form puparia; in some cases the puparia were formed in the closing pith plug (Figs. 9, 10). In the one nest in which the single maggot infested cells above the entrance, it wriggled upward after it was full grown and formed a puparium 12 cm above the nest entrance.

There are no previous host records for this or other North American species of *Eustalomyia*. Several European species have been reared from various crabronine wasps.

UNKNOWN MUSCOID FLY

There were five additional nests of the hibiscus wasp (10761 E; 71162 I; 91662 M, N, V) infested by a muscoid fly or flies, which emerged before the nests were opened for study. Not all of the empty puparia were preserved, but at least two of them were of a different genus and species from any of the three species discussed previously. In these two nests (91662 M, V) one maggot destroyed all cells in a 4-celled nest; in the other nest the maggot destroyed an undetermined number of cells.

Vidia cooremani Baker

This saproglyphid mite was discovered during this study (Baker, 1964). Its host is the hibiscus wasp, *Ectemnius paucimaculatus*. I obtained the first hypopi or deutonymphs on the abdomen of a male wasp (51963 A) netted on 19 May 1963. There were eight, light-tan hypopi on the left side of the first tergum and three more near the base of the second sternum. They were about 200 μ long and 125 μ wide.

I collected three additional hibiscus wasp males (52663 B, C, D) a week later, each bearing one or more hypopi on the abdomen. One had 3 mites on the first tergum; the second had practically all of the first tergum covered by 25 mites plus 4 more on the first sternum and 12 more on the right side of the second sternum; the third wasp had only a single hypopus on the base of the second sternum and a second on the right side of the propodeum.

On 16 June I found three nests in which I discovered mite infestations subsequently. One nest (61663 P) was opened for study on 16 June. The single cell in this completed nest contained a single mite on one of the flies; the contents of this cell shriveled up several days later and I was unable to recover the mite. I opened the other two nests (61663 U, X) on 28 June, on which date all of the wasp occupants were in cocoons. There were a number of mite hypopi clustered around the anterior end of the wasp cocoons in cells 1 and 4 of a 4-celled nest, as well as some dispersed, pale protonymphs on the cocoon walls. I opened one of the cocoons and found a healthy wasp pupa but no mites. In the other 6-celled nest there were mites on the cocoons in cells 1 and 3; the contents of cell 2 were moldy. The pale, 8-legged protonymphs were 233–250 μ long, and the light-tan deutonymphs (hypopi) were 167–200 μ long. I searched through the debris in each mite-infested cell, but I was unable to find dead adult mites or eggs.

Cooreman and Crèvecoeur (1948) published an extensive account of the life cycle of the European *Vidia concellaria* Coor., a symbiont of the ground-nesting sphecid wasp *Cerceris arenaria* L. in Belgium. The scanty data which I obtained for the American species agree very well with some of their observations on *V. concellaria*. It is quite probable that in general details the biology of the two species is similar. In brief, *concellaria* hypopi also occur on the adult wasp and drop off in the wasp's cell as it is being provisioned. The hypopi or deutonymphs transform to tritonymphs and then into adults in a very short time. The adult female mites deposit eggs in the cell soon after the wasp larva has spun a cocoon. The eggs hatch in 24–28 hours and the resulting larvae transform to protonymphs in another 2–3 days. The mite adults, larvae and protonymphs, all live as scavengers on and in the beetle (prey) remains. However, they stated that the deutonymphs were found in the beetle carcasses attached to the *Cerceris* cocoon, rather than on the cocoon itself. When the adult *Cerceris* left the cocoon the following spring, the deutonymphs attached themselves to the wasp's body. *Vidia* *concellaria* has only a single generation a year, at least on *Cerceris arenaria*, which is univoltine in Belgium, whereas the American species must have two or more generations a year.

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